

action of its return spring portion 236 so that the regulating pawl 231 leaves the back of the pinion gear 210. Then, the pinion gear 210 is returned backwards by the action of the return spring 240 to come out of meshing engagement with the ring gear 100 of the engine and to bring its rear end into abutment against the flange-shaped protrusion 222 of the output shaft 220. In short, the pinion gear 210 is returned to the stage before the start of the starter (as shown in FIG. 23C).

As a result that the plunger 610 is returned downwards, moreover, the lower movable contact 611 comes into abutment with the upper face of the stationary core 642 of the magnet switch 600 so that the lead wire 910a of the upper brush 910 is turned conductive in the course of the upper movable contact 612, the resistor 617, the lower movable contact 611, the stationary core 642, the magnet switch cover 640 and the brush holding member 900. In short, the upper brush 910 and the lower brush 910 are short-circuited through the brush holding member 900. Meanwhile, an electromotive force is generated in the armature coil 530 by the inertial rotation of the armature 540. Moreover, this electromotive force is short-circuited through the upper brush 910, the brush holding member 900 and the lower brush 910 so that the braking force is applied to the inertial rotation of the armature 540. As a result, the armature 540 is abruptly stalled.

[Effects of Embodiment]

Since, in the embodiment thus far described, the lower-layer coil ends 537 and the upper-layer coil ends 534 forming the first and second connecting portions are held in abutment against the end face of the armature core 500 through the insulators, the inertias of the cylindrical commutators and the armature coils in the prior art are reduced to reduce the inertia drastically as that of the armature 540. As a result, while the pinion gear 210 is meshing with the ring gear 100, the impact torque at the time of inertial rotation can be reduced to reduce the module of the used gear to $M=0.9$. At the same time, the reaction force R , of the armature bearing 570 can be reduced by the weight of the cylindrical commutator of the prior art, and its support distribution can be reduced to $1/L$, as compared with the value $1/L$ of the prior art, to reduce the diameter of the bearing. As a result, the sun gear 310 can have its tooth number reduced to $Zs=8$ (i.e., the dedendum diameter of $=5.85$), and the reduction ratio can be set to $I=8.25$. Hence, the motor volume can be reduced to $I=8.25$, as compared with $I=6$ or less in the prior art, so that the motor can be small-sized.

Due to the grooves 535 in the gaps of the individual upper-layer coil ends 534, moreover, the centrifugal wind is produced radially outward by the grooves 535 of the upper-layer coil ends 534 as the armature coil 530 rotates. Moreover, the air thus established by the individual grooves 35 of the individual upper-layer coil ends 534 abutting against the brushes 910 and sucked from the opening 410 of the housing 400 is guided to the inside between the upper-layer coil ends 534 at the rear side and the brush holding member 900 in the course of the inside of the housing 400, the notches 364 in the upper side of the center bracket 360, the motor partition communication holes 810, the gaps 590 between the main magnetic poles 551, the brush holding member communication

holes 980, the inside of the end frame 700 and the inlet port 970.

The centrifugal wind established between the upper-layer coil ends 534 at the rear side and the brush holding member 900 is discharged, after having cooled down the sliding faces and the peripheries of the brushes 910, together with the brushed powder to the outside of the starter from a discharge hole 503 formed in the lower end of the yoke 501.

Since the upper-layer coil ends 534 acting as the commutator act as the centrifugal fan to establish the centrifugal wind, it is possible to keep the temperature of the sliding portions between the upper-layer coil ends 534 and the brushes 910 to a low level.

As a result, the shortage of the thermal radiation, which is caused at the speed reduction ratio $I=8.25$ by the less motor surface area than that of the prior art, is solved by the air-cooling effect so that the size of the motor can be reduced with a sufficient heat resisting performance.

Moreover, the means for restricting the power supply to the starter motor 500 within a predetermined time period by sensing the heat liberated from the motor may be exemplified by another protecting unit which is arranged with heat sensing elements such as bimetal elements in the vicinity of the heat sensing portions, the brush device 900, the field device 550, the yoke 501 and the end frame 700 to turn OFF the power supply of the magnet switch 600 to the attraction coil 650, when the motor temperature reaches a predetermined level, thereby to stop the power supply to the starter motor. The bimetal elements are of the working type but may be exemplified by the self-holding type in which the OFF state is held when the element is opened. In case the aforementioned protecting device is used together, the armature having a generally helical commutator in the armature core need not be used together, but the armature of the prior art may be used. Still moreover, a timer unit may be assembled in the starter control circuit to restrict the time period for the power supply to the starter.

Thus, according to the present invention, the starter can have its size and weight remarkably reduced, as compared with the starter of the prior art, by clarifying the optimum range of 6 to 10 for the high reduction ratio range $I=6$ or more, unlike the prior art, and by setting $I=8.25$.

Since the starter can be drastically small-sized according to the present embodiment, the starter can be effectively mounted in the dead space, which cannot mount it in the prior art, such as the engine flywheel or the oil pan below the engine.

INDUSTRIAL APPLICABILITY

As has been described hereinbefore, the starter according to the present invention can be utilized as a starter having a reduction gear mechanism for starting an internal combustion engine.

We claim:

1. A starter comprising:

a starter motor including an armature core having an armature coil wound thereon and an armature shaft for holding said armature core rotatably;

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a drive shaft having a pinion meshing with a ring gear of an engine; and
 a reduction gear mechanism interposed between said drive shaft and said armature shaft of said starter motor for reducing the rotation relative to said armature shaft to transmit the reduced rotation to said drive shaft, wherein said reduction gear mechanism having a speed reduction [ration]ratio of more than 6:1 to less than 10:1,
 wherein said reduction gear mechanism is a planetary reduction gear mechanism including:
 a sun gear formed at one end of said armature shaft;
 a planetary gear mounted on one end of said drive shaft and meshing with said sun gear; and
 an internal gear meshing with said planetary gear for forming a stationary side,
 wherein said reduction gear mechanism is of a single unit type and the planetary gear transmits rotation of said armature shaft to said drive shaft.

2. A starter according to claim 1, wherein said armature coil includes:
 upper-layer and lower-layer coil members fitted in slots of said armature core;
 first connection portions connected to one end of said lower-layer coil member and extending generally in parallel with an axial end face of said armature core and in said shaft direction; and
 second connection portions connected to one end of said upper-layer coil member and the other end of said first connection portions and extending generally in parallel with said first connection portions.

3. A starter according to claim 2, further comprising:
 insulators interposed between said first connection portions and said armature core and between said first connection portions and said second connection portions; and
 brushes arranged slidably on said second connection portions.

4. A starter according to any of the claims 1 to 3, further comprising:
 a cooling fan for cooling sliding faces of said starter motor with said brushes.

5. A starter according to claim 4, further comprising:

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grooves formed between said second connection portions to protrude with respect to a rotating direction
 of said armature shaft so as to act as said cooling fan for producing a cooling wind when said armature coil rotates.

6. A starter according to any of the claims 1 to 3, further comprising:
 limit means for limiting the power supply to said starter motor within a predetermined time period.

7. A starter according to claim 1, wherein said reduction gear mechanism has a speed reduction ratio of about 8.25:1.

8. A starter according to claim 1, wherein the reduction ratio is set so that the total volume $V_T = V_1 + V_2$, where V_1 =volume of the starter motor and V_2 =the volume of the planetary gear mechanism, is substantially at a minimum.

9. A starter according to claim 1, satisfying the following relationship:
 $I = Z_i/Z_s + 1$ where Z_i =the number of teeth of the internal gear, Z_s =the number of teeth of the sun gear, and I =the reduction ratio.

10. A starter as in claim 9, wherein the $Z_i=58$ and $Z_s=8$.

11. A starter as in claim 1, wherein an external diameter of the motor is set to 68 mm and an external diameter of the internal gear is set to 58 mm.

12. A starter according to claim 1, wherein said reduction gear mechanism has a speed reduction ratio of 6.25:1 to 9:1.

13. A starter according to claim 1, wherein said reduction gear mechanism has a speed reduction ratio of 6.25:1 to 8.25:1.

14. A starter according to claim 1, wherein a rated output of said starter is in a range of 0.6 to 3.0 kilowatts for 12 volts or in a range of 2.0 to 5.5 kilowatts for 24 volts.

15. A starter according to claim 1, wherein a module of said sun gear is in a range of 0.8 to 1.25.

16. A starter according to claim 1, wherein a dedendum diameter of said sun gear is more than 5 mm.

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ABSTRACT

A starter is provided that includes a starter motor having an armature core with an armature coil wound therearound and an armature shaft for rotatably holding the armature core. A drive shaft is further provided having a pinion that meshes with a ring gear of an engine. A reduction gear mechanism is interposed between the drive shaft and the armature shaft for reducing the rotation relative to the armature shaft to transmit the reduction rotation to the drive shaft. The reduction gear mechanism has a speed reduction ratio of 6:1 to 10:1.